Drinking Water

The American public enjoys safe drinking water because public utilities and other drinking water providers

- *select the best available sources and protect them from contamination;*
- *use water treatment, including disinfection, to control contaminants; and*
- *prevent water quality deterioration in the distribution system.*

In the United States, these practices have virtually eliminated waterborne threats such as typhoid fever and cholera; however, some public health concerns remain. Waterborne disease outbreaks caused by pathogenic bacteria, viruses, and parasites continue to be reported periodically, demonstrating that the safety of drinking water can still be compromised if treatment is inadequate. Surface water and groundwater sources can be contaminated with many different types of chemical contaminants, including natural (e.g., arsenic) and manmade (e.g., pesticides) substances. Furthermore, the disinfection process itself creates a number of potentially toxic chemical byproducts. Some groups such as infants, children, and people with weakened immune systems are known to be particularly sensitive to certain waterborne pathogens and chemicals.

Under the Safe Drinking Water Act, EPA conducts research that provides a strong scientific foundation for standards that limit the public's exposure to drinking water contaminants. EPA's drinking water research program supports major regulatory activities including the Arsenic Rule, the Microbial/Disinfection Byproduct Rules, and future decisions on unregulated waterborne pathogens and chemicals. ORD is conducting research on waterborne pathogens (e.g., *Cryptosporidium* and Norwalk virus), arsenic, disinfection byproducts and other chemical contaminants to support EPA's decision-making process. Recent research accomplishments to protect drinking water quality are highlighted in this chapter.

ARSENIC MODE OF ACTION

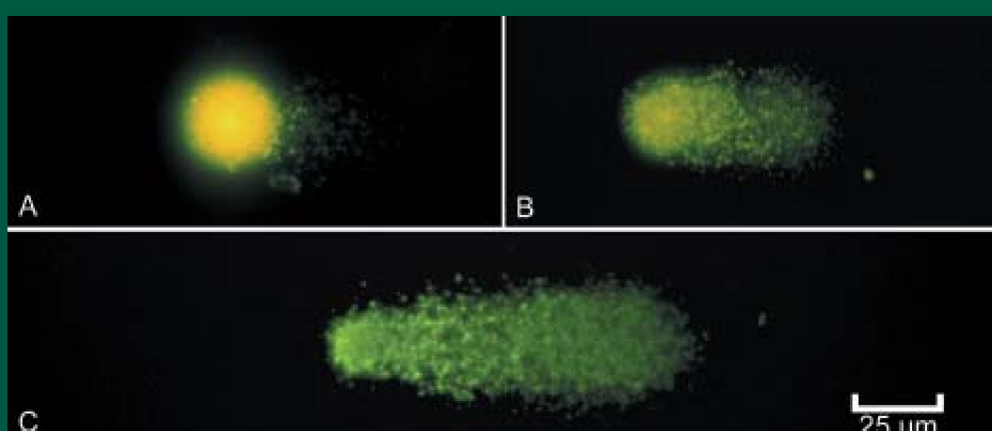
Inorganic arsenic occurs naturally in soil and groundwater in certain parts of the United States, particularly those with volcanic activity or hot springs. People ingesting high levels of arsenic may experience health problems such as cardiovascular disease, strokes, peripheral neuropathy (a disorder of the nerves), diabetes, abnormal fetal development, and several types of cancer. While studies in foreign countries with very high levels of arsenic in drinking water have demonstrated that arsenic can be

Preparing water samples for toxic element analysis.

harmful, the actual mechanisms by which health problems occur are not well understood. Research on specific ways that arsenic affects the body can provide important information for estimating the risk of arsenic, particularly at the low levels of exposure found in some areas of the United States.

A team of ORD scientists, collaborating with researchers at the University of North Carolina at Chapel Hill, NC, and the University of British Columbia in Vancouver, Canada, studied the effects of several forms of arsenic on isolated DNA and on DNA in cultured human lymph cells. The researchers found that some arsenic metabolites caused direct damage to DNA in both test settings. This finding is significant because it had been assumed that compounds produced during arsenic metabolism were less toxic than arsenic itself. Also, prior to this research, there was little evidence that arsenic interacted with DNA, which had led scientists to believe that arsenic caused cancer through indirect mechanisms. The results of this study support the hypothesis that arsenic may be able to cause cancer by interacting directly with DNA.

These findings provide a strong impetus for additional studies on arsenic's mode of action and the role of metabolism in the development of cancer and other toxic effects. This new information will improve the scientific foundation for risk assessments conducted in support of future regulatory reviews of EPA's standard for arsenic in drinking water.



As fragments of damaged DNA migrate in the electric field created in this single-cell gel assay, they produce the appearance of the tail of a comet. These images are representative of those seen in (A) control and pentavalent methyl arsenic compounds, no DNA damage; (B) trivalent methyl arsenic, some DNA damage; and (C) even very low concentrations of trivalent dimethyl arsenic, appreciable DNA damage.

DISINFECTION BYPRODUCTS

ORD scientists are using innovative analytical techniques to learn more about the chemistry of several disinfectants that are being increasingly used by water utilities as alternatives to the standard treatment product, chlorine. These alternative disinfectants, which include ozone, chlorine dioxide, and chloramine, may be used either alone or in combination with chlorine. Alternative disinfectants are popular in the United States because they destroy harmful microorganisms while allowing treatment plants to more easily comply with EPA regulations that limit levels of potentially harmful compounds in drinking water. Compared to chlorine, alternative disinfectants typically produce lower levels of potentially harmful byproducts. However, there is concern that these new treatments may produce previously unrecognized, potentially harmful byproducts.

Using various laboratory techniques, ORD scientists have identified many new disinfection byproducts from drinking water treated with single disinfectants or with combinations of two or more disinfectants. In treatments using only one chemical at a time, chlorine dioxide and ozone produced the least number of potentially harmful byproducts, whereas chlorine and chloramine produced many potentially harmful byproducts. Of the disinfectants tested, chlorine produced the highest overall concentrations of potentially harmful byproducts.

Disinfection byproducts are formed when a disinfectant such as chlorine or ozone is used to destroy harmful microorganisms in drinking water.

The drinking water in some communities contains bromine compounds. There is some evidence from laboratory studies that high doses of bromine-containing compounds may be more harmful than chlorine-containing compounds in some situations. Therefore, ORD scientists extended their research on disinfection byproducts to examine byproducts produced when source waters contain relatively high concentrations of bromine. They found that elevated bromine levels caused a shift from chlorinated to brominated disinfection byproducts. More research is needed to clarify

Electron micrograph of Giardia*, a water-borne disease-causing microorganism.*

what, if any, public health risks may accompany the presence of brominated disinfection byproducts in drinking water.

In a related effort, scientists from ORD, the University of North Carolina, and the Metropolitan Water District of Southern California are conducting a Nationwide Occurrence Study of disinfection byproducts. A multidisciplinary group of experts ranked more than 500 disinfection byproducts according to predicted health problems. The 50 "highest priority" disinfection byproducts are being measured in the drinking water of U. S. communities. More chemicals are being added to the list as they are identified as potentially hazardous byproducts. The results of this study will help focus future health effects research, with the ultimate goal of minimizing hazardous byproducts and keeping drinking water as safe as possible for consumers.

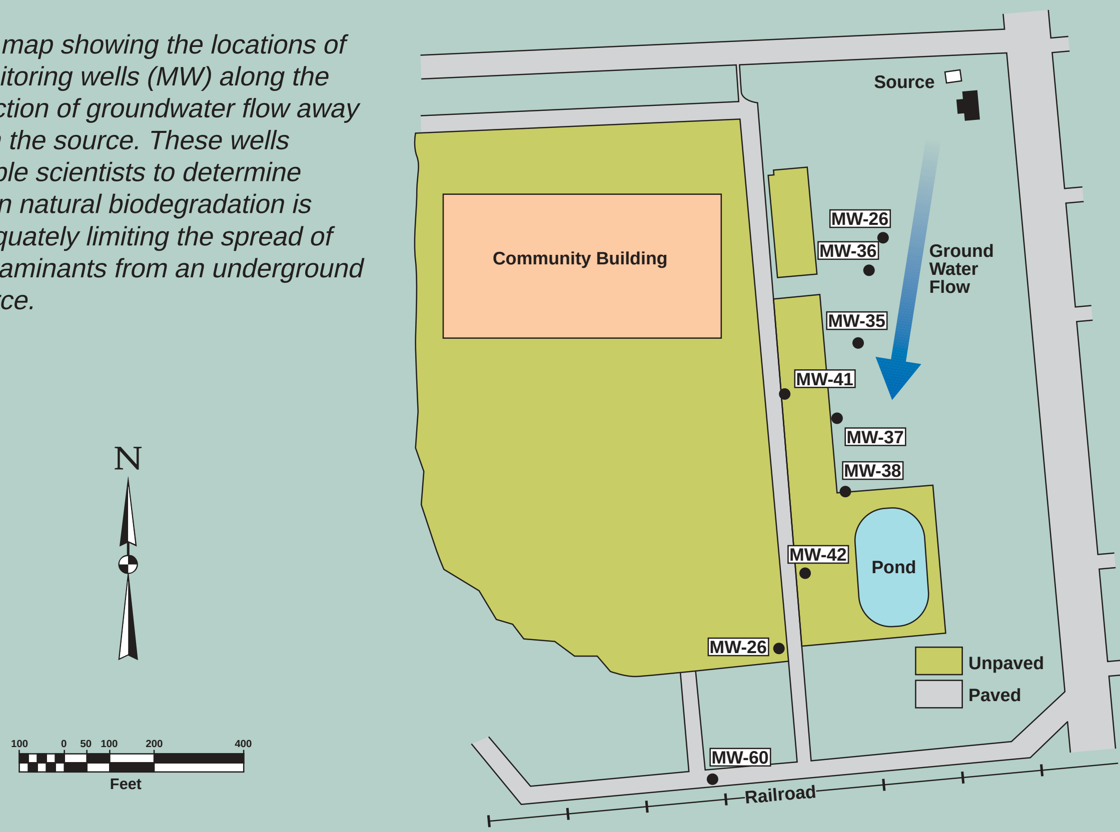
MTBE IN GROUNDWATER

In different areas of the country, methyl tert-butyl ether (MTBE) is added to gasoline either to reduce emissions that cause ground-level ozone or to enhance octane. If underground storage tanks leak or gasoline spills, groundwater can be contaminated with MTBE, adversely affecting the taste and odor of drinking water. Although MTBE is considered to be a potential human carcinogen at high doses, the potential health risks of exposure to MTBE at low levels in drinking water have not been determined.

Biodegradation is the breakdown of chemicals by microorganisms such as bacteria and fungi.

An important area of EPA research has been to develop various technological approaches for reducing MTBE in the environment to levels that are acceptable from both aesthetic and public health perspectives. Monitored Natural Attenuation is one of the innovative technologies that EPA is evaluating.

Monitored Natural Attenuation relies on the natural processes of dilution, dispersion, sorption, and biodegradation to reduce the concentration, mass, mobility, and toxicity of contaminants in soil over a reasonable time period. After reviewing existing research on Monitored Natural Attenuation, EPA's Science Advisory Board recommended



Site map showing the locations of monitoring wells (MW) along the direction of groundwater flow away from the source. These wells enable scientists to determine when natural biodegradation is adequately limiting the spread of contaminants from an underground source.

that the Agency investigate how well MTBE and other fuel additives biodegrade under various field conditions. ORD researchers collaborated with industry scientists to evaluate the biodegradation of MTBE at 74 gasoline service stations in the eastern United States. The scientists determined that natural biodegradation limits the spread of MTBE contamination at many underground storage tank sites. They also learned that measuring some geochemical parameters (e.g., sulfate, methane) in water samples from monitoring wells will help identify sites where biodegradation can effectively limit the spread of MTBE and other contaminants.

LOOKING TO THE FUTURE

A few anticipated milestones in ORD's Drinking Water research program include

- *risk assessments for selected waterborne pathogens and chemicals on EPA's Contaminant Candidate List of unregulated contaminants*,
- *information on potential associations between exposure to disinfection byproducts in drinking water and reproductive problems*, *and*
- *cost-effective technologies for removing arsenic from drinking water.*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